Performance Evaluation of Orange Peels as Anti-Scaling Agent for Pretreatment of Water

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Abstract

This study described the development and application of efficient anti-scalant material using orange peels. Specifically, 2 g of dried orange peels screened up to 450 µm average particle, 10 mL of methanol was used to prepare 100 mL anti-scalant solution at room temperature. FT-IR analysis showed that the anti-scalant characteristics is similar to citric acid which is an indication for an efficient anti-scalant. At a dosage of 1 g/L based on the mass of dried orange peel powder, a solution containing calcium carbonate was found to increase the solubility from 14 mg/L to 60 mg/L at a pH of 6.2.

Keywords: anti-scalant, orange peels, extraction, pretreatment, membrane

Introduction

Fouling is a major hurdle that must be overcome for the implementation of membranes to water treatment worldwide (Bhattacharyya et al., 2000). Fouling is a phenomena whereby colloidal or particulate matter are deposited either on the membrane surface or right in the membrane pores which hinder transport through the membrane (Boerlage et al., 2002). Water flux and solute rejection performance are reduced when water containing foreign particles such as particulates, colloids, macromolecules, or microbes is treated using a membrane technology. In addition, the foreign material forms a cake layer which drastically reduces the overall performances of the membrane (Baker, 2004). Fouling causes flux declines and leads to high membrane operation cost because high energy is needed to obtain high flux through a fouled membrane. Also a fouled membrane need cleaning and eventually a total replacement (Basile et al., 2015). Fouling caused by inverse solubility salts are known as scaling or crystallization fouling (MacAdam and Parsons, 2004). Substances that caused scaling includes calcium carbonate, calcium sulphate, barium sulphate and silica. When water on the feed side becomes super saturated with these substances, scaling of the membrane is the result. Super-saturated salts can precipitate on the membrane surface building a thin layer, which hinders mass transfer through the membrane. Scaling always occurs at the membrane surface because of the increased salt concentration near the membrane caused by concentration polarization. Scaling can dramatically reduce permeate flux, and has to be avoided by all means. One of the methods to remove scale is by flushing the membrane with acid but a major issue with this method is the difficulty encounter when taking the crystalline mud out of the module. The best method is to pretreat the feed water and keep the concentration of the scale forming salt under saturation level by adjusting the pH or by preventing the precipitation using anti-scalant (MacAdam and Parsons, 2004). Commonly used chemical additives as anti-scale agents are solutions of low molecular weight polyacrylic acid, phosphoric acid, and phosphate esters (MacAdam and Parsons, 2004). Citric acid has been found to be an effective green scale inhibitor (Ghizellaoui et al., 2017). Orange peels are fruit wastes found in abundance in South Africa. Agricultural wastes such as banana peels, sugar cane baggase and orange peels has been proven highly efficient in wastewater treatment (Oyewo et al., 2016). Among the above listed, it has been reported that orange peels have the potential as an alternative raw material for citric acid

fermentation (Rivers et al., 2008), it is hereby speculated that orange peels are highly efficient as anti-scalant. In this study, the evaluation of orange peels as natural anti-scalant was demonstrated due to its higher citric acid content using solubility method. The main aim was to use ecofriendly and highly economical anti-scalant material to optimize the commercially available anti-scaling agents in water pre-treatment.

Methods

Oranges peels obtained from Pretoria, South Africa, was carefully removed from its fruit and processed into powdered form as shown in Figure 1.

The dried solid powder was characterized using transform infrared spectroscopy (FT-IR) and Energy dispersive x-ray analysis (EDX) (Oyewo et al., 2016, Mafra et al., 2013). The anti-scalant was extracted from the orange peel powder as shown in Figure 2.

Extract prepared as a filtrate from adding 90 mL of deionized water and 10 mL of methanol to 2 g of the orange peel powered was used at different volumes of 5 mL, 10 mL, 15 mL, 20 mL, 25 mL and 30 mL for this investigation. Solutions of calcium carbonate were prepared using different masses of calcium carbonate which were 0.10 g, 0.15 g and 0.20 g in 100 mL of deionized water. The extract was added to each of the prepared solution at each of the volumes already stated in order to observe its effect on the solubility of calcium carbonate. The resulting solution was filtered. The pH of the filtrate was taken and the concentration of the calcium carbonate determined using ICP-OES.

Results and discussion

The discussion of results is divided into three parts. The first was on the characterization of the powder obtained after processing the orange peels. The aim was to discover the presence of elements and radicals that could indicate acidic properties in the orange peel powder. The second part was the extraction of the anti-scalant from the orange peel powder using a mixture of water and methanol. The third was the solubility test results whose aim was to confirm if the extract obtained from orange peel powder can actually increase the dissolution of the calcium carbonate and keep its concentration under saturation.

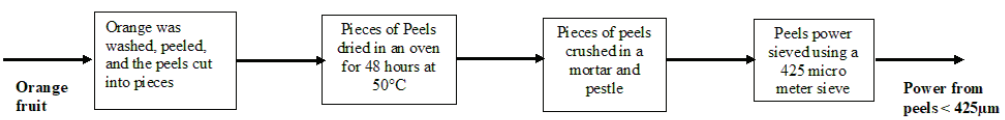

Figure 1 *Flow diagram for the preparation of orange peels power from orange fruits.*

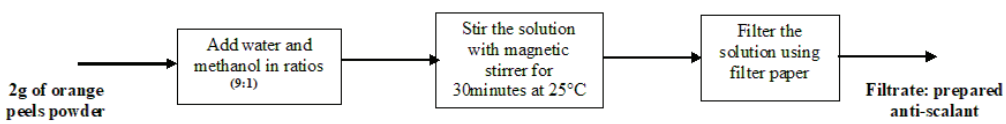

Figure 2 *Chemical extraction method to extract anti-scalant from orange peels powder.*

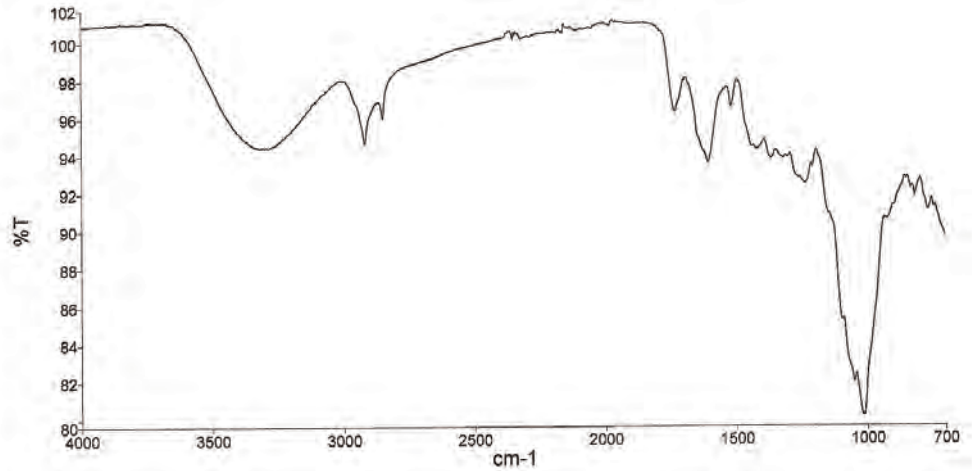

Figure 3 *FT-IR results of the orange peels powder.*

Figure 3 shows the FT-IR results of the orange peel powder. The FT-IR spectrum of the orange peel powder shows the complex nature of the powder, displaying a broad spectrum of adsorption peaks. The broad, intense absorption peaks around 3,400 cm-1 are indicating of is a strong presence of acid O-H, resulting from the O-H stretching mode of hydroxyl groups characteristic of citric acid as observed by Singh et al. (2014), who analyzed Fe_3O_4 coated with citric acid. The bands at 2,900 cm-1 and 2,850 cm-1 were due to the presence of C-H in the powder (Al-Qodah and Shawabkah, 2009). The peak around 1,635 cm-1 is due to the C=C stretching that can be attributed to the aromatic C-C bond, and the peak at 1,072 cm-1 can also be explained by the presence of either C-O symmetric or asymmetric stretching vibration (-C-O-C- ring) (Khaled et al., 2009).

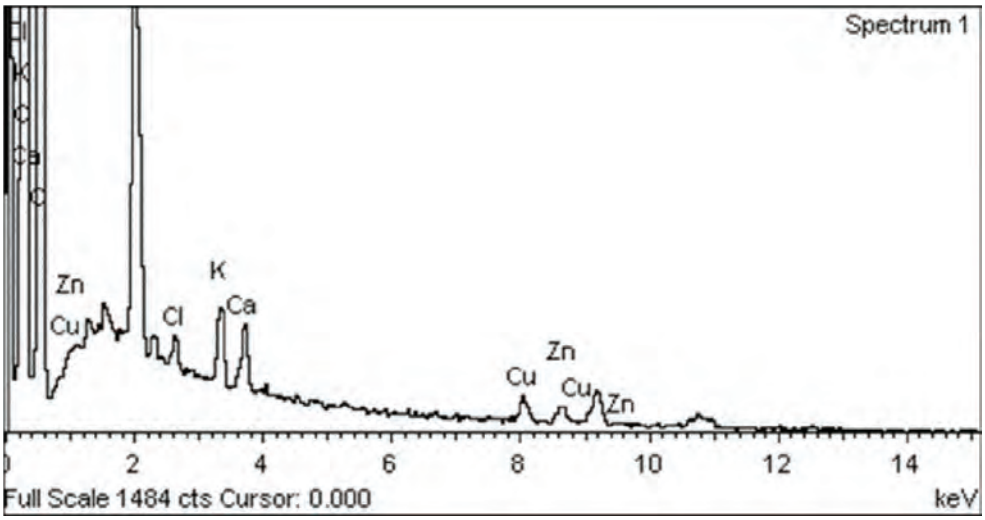

Figure 4 *EDX for the orange dried peels powder.*

The result was further confirmed by the EDX showing a significant presence of Carbon (67.86%) and Oxygen (31.62%) because they are organic materials. This is due to the fact that orange peels have tendency to demonstrate acid characteristics similar to citric acid.

Anti-scaling agents are a family of chemicals designed to inhibit the formation and precipitation of crystallized mineral salts that form scale (MacAdam and Parsons, 2004). It has been established that the tendency for scale formation is lower in an acidic environment (MacAdam and Parsons, 2004, Geise et al., 2010). The resulting extract (filtrate), obtained after adding water and methanol in ratios 3:1,4:1 and 9:1 to 2 g of the orange peel power and filtering, was tested for pH. Results are shown in Table 1. The extract prepared with the addition of water and methanol in the ratio 9:1 is more acidic than others at pH of 5.93., and was used for carbonate dissolution experiment. It is possible that the extract could have anti-scalant effect also due to threshold inhibition, crystal modification and dispersion but only dissolution effect was tested in this work.

Figure 5 shows the effect of addition of various volume of the extract to different concentration of calcium carbonate solution. The result shows that at a dosage of 5 mL, solubility of calcium carbonate increases from 14 mg/L to a minimum of 60 mg/L at room temperature for a solution with calcium carbonate concentration of 2000 mg/L. This is possibly due to higher solubility of calcium carbonate in acidic environment (MacAdam and Parsons, 2004) as the average pH of the resulting solutions was 6.2. However, in real situation, the concentration of calcium carbonate in not likely to get up to 1000 mg/L (Fritzmann et al., 2007). Extremely hard water is known to have concentration of 554 mg/L (Ghizellaoui et al., 2017) and the less the concentration the more effective the antiscalant. The estimated dosage is 1 g/L based on the mass of the dried orange peel powder used to prepare the extract and the volume added to the carbonate solutions.

Table 1. *Extraction of orange dried peels powder using distilled water and methanol at 25 °C.*

Mass (orange dried peels powder) (g)	Volume (distilled water and methanol) (ml)	pH
2	75 and 25	6.13
2	80 and 20	6.65
2	90 and 10	5.93

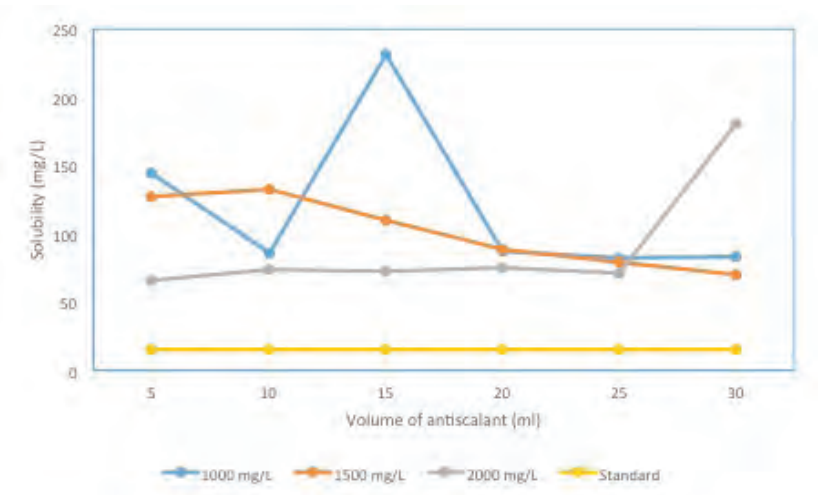

Figure 5 *Effect of various volume of antiscalant on CaCO3 dissolution*

Conclusion

The following conclusions are drawn from this work:

1. Powder prepared by drying and grinding orange peels to 450μm average particle size demonstrated characteristics similar to citric acid which has been found to be an effective anti-scalant.
2. An extract prepared by adding 2 g of the dried powder to 100ml of solution containing 90ml of water and 10ml of methanol was found to have average pH of 5.95 at room temperature.
3. Addition of 5 ml of the extract to a solution containing calcium carbonate was found to increase the solubility from 14mg /L to an average of 60 mg/L at an average pH of 6.2 at room temperature.
4. At a dosage of 1 g/L based on the mass of dried orange peel powder, calcium carbonate scale formation can be effectively hindered.
5. Orange peels show a potential for anti-scalant preparation and can be a cheap alternative to commercially available anti-scalant and its use can also be advantageous for the environment in management of fruit wastes.

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